

Opportunity Fuels for CHP: Alternative to High Gas Prices?

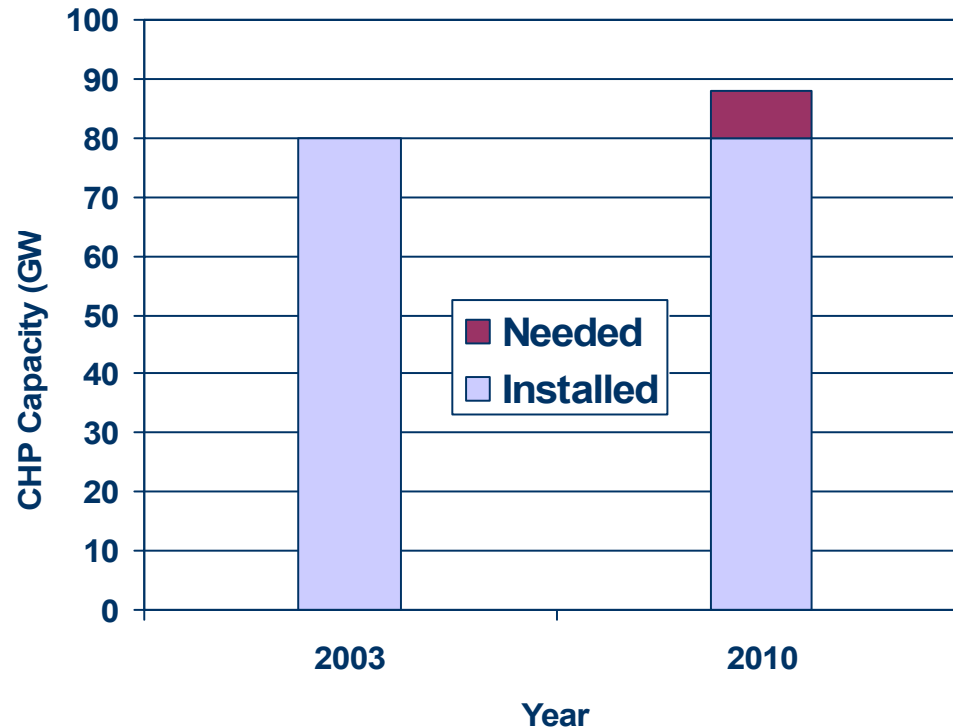
5th Annual CHP Roadmap
Workshop
Austin, TX
September 22, 2004

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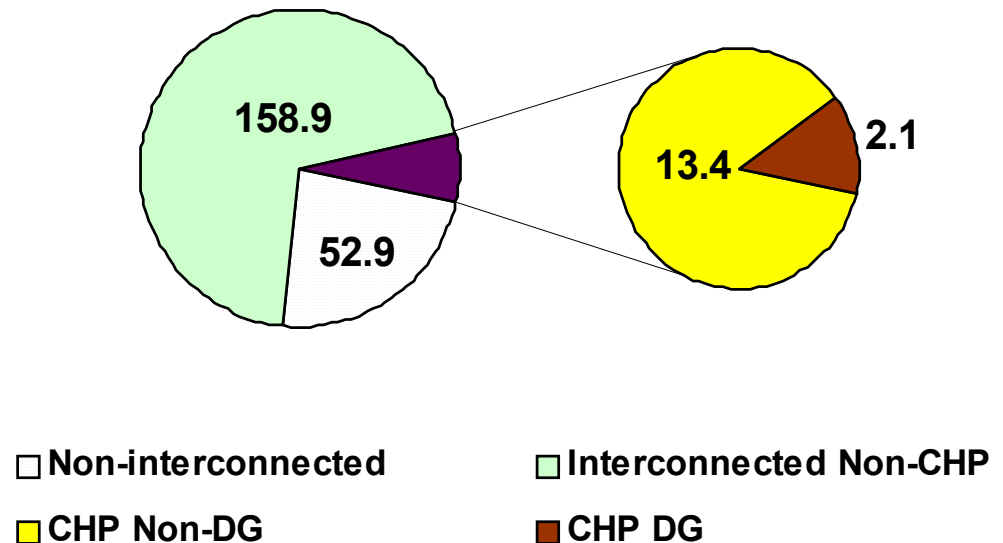
The Road to 92 GW: How Far Are We?



Recent CHP Capacity Additions

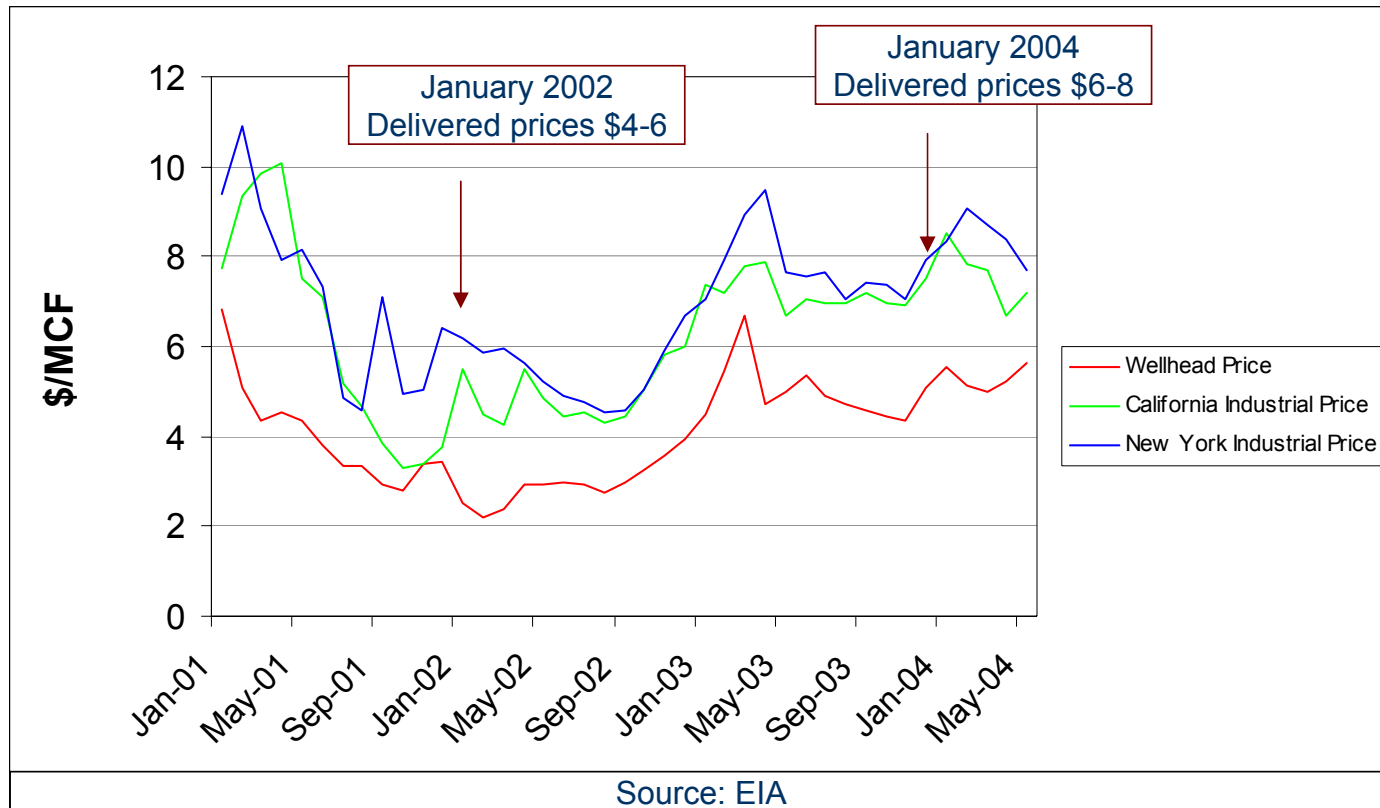
- 15.5 GW change in CHP reflects buildup after California crisis and other market changes
- 87 percent of new CHP is units over 60 MW, mostly gas-fired combined cycle “merchant” CHP
- Few central stations currently being built
- If we continue adding small CHP at the current rate without adding any large CHP, we will add only 5 GW by 2010

**Capacity Added 2001-2003
(GW)**

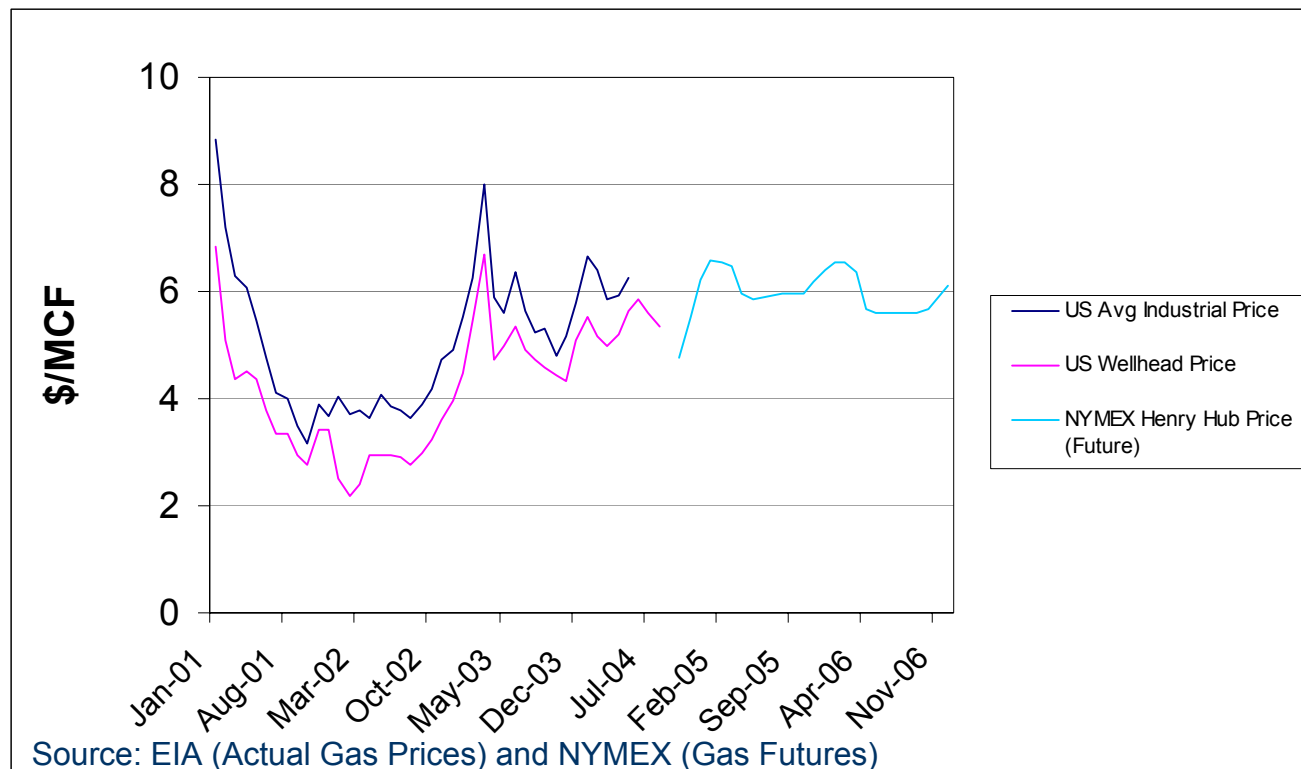


Source: *The Installed Base of U.S. Distributed Generation, 2004 Edition*, RDC. Includes both utility and non-utility, interconnected and non-interconnected, capacity additions of all sizes

Natural Gas Prices Have Risen Substantially...



... And Are Expected to Stay High



The Opportunity for Alternative CHP Fuels

- High natural gas prices have decreased spark spreads and reduced market potential
- Proposed solutions focus on increasing natural gas supply or reducing demand, neither will likely help much in the short run
- We still need to add 12 GW of CHP capacity by 2010. Are there other alternatives to consider?

Alternative Solution: Develop Other, Cost-Effective Fuels

- Opportunity Fuel: any fuel that has the potential to be used for economically-viable power generation, but is not traditionally used for this purpose
- Opportunity fuels include:
 - Anaerobic Digester Gas
 - Biomass (General)
 - Biomass Gas
 - Black Liquor
 - Blast Furnace Gas
 - Coalbed Methane
 - Coke Oven Gas
 - Crop Residues
 - Food Processing Waste
 - Industrial VOC's
 - Landfill Gas
 - Municipal Solid Waste
 - Orimulsion
 - Petroleum Coke
 - Sludge Waste
 - Textile Waste
 - Tire-Derived Fuel
 - Wellhead Gas
 - Wood
 - Wood Waste

Opportunity Fuel Performance Chart: Selecting the Top Candidates

Opportunity Fuel	Availability	Heating Value	Fuel Cost	Equipment Cost	Emissions / Environment	DER/CHP Potential	Rating	Limitations
Anaerobic Digester Gas	●	●	●	●	●	●	5.0	Need anaerobic digester
Biomass Gas	●	●	●	○	●	●	4.0	Gasifiers extremely expensive
Black Liquor	○	●	●	●	●	●	3.0	Most BL already used up by mills
Blast Furnace Gas	○	○	●	●	●	○	2.0	Limited availability, low Btu
Coalbed Methane	●	●	●	●	●	●	5.0	Coal mines - lack CHP demand
Coke Oven Gas	○	●	●	●	●	●	3.0	Availability - most already used
Crop Residues	●	●	○	●	●	●	3.0	Difficulty in gathering/transport
Food Processing Waste	●	●	●	●	●	●	4.0	Limited market, broad category
Ethanol	●	●	●	●	●	●	4.0	Currently only used for vehicles
Industrial VOC's	○	○	●	●	●	●	2.0	Must be used w/ NG turbine
Landfill Gas	●	●	●	●	●	●	4.5	Landfills – little demand for CHP
MSW / RDF	●	○	●	○	●	●	3.0	Low heating value, contaminants
Orimulsion	○	●	●	●	●	●	2.5	Orimulsion not available in U.S.
Petroleum Coke	●	●	●	●	○	○	3.5	Many contaminants; large apps
Sludge Waste	●	○	●	○	●	○	2.5	Low heating value, contaminants
Textile Waste	●	●	●	●	●	○	3.0	Must be cofired; larger apps
Tire-Derived Fuel	●	●	●	●	●	●	4.0	Best suited for large apps
Wellhead Gas	●	●	●	●	●	●	4.5	Oil / gas wells – no CHP demand
Wood (Forest Residues)	●	●	●	●	●	●	4.0	Fuel can be expensive
Wood Waste	●	●	●	●	●	●	4.5	Waste may have contaminants

Key: ● = excellent / not an issue, ● = average / could become an issue, ○ = poor / major issue

Led By Biomass Gas, Opportunity Fuels Have Significant Potential

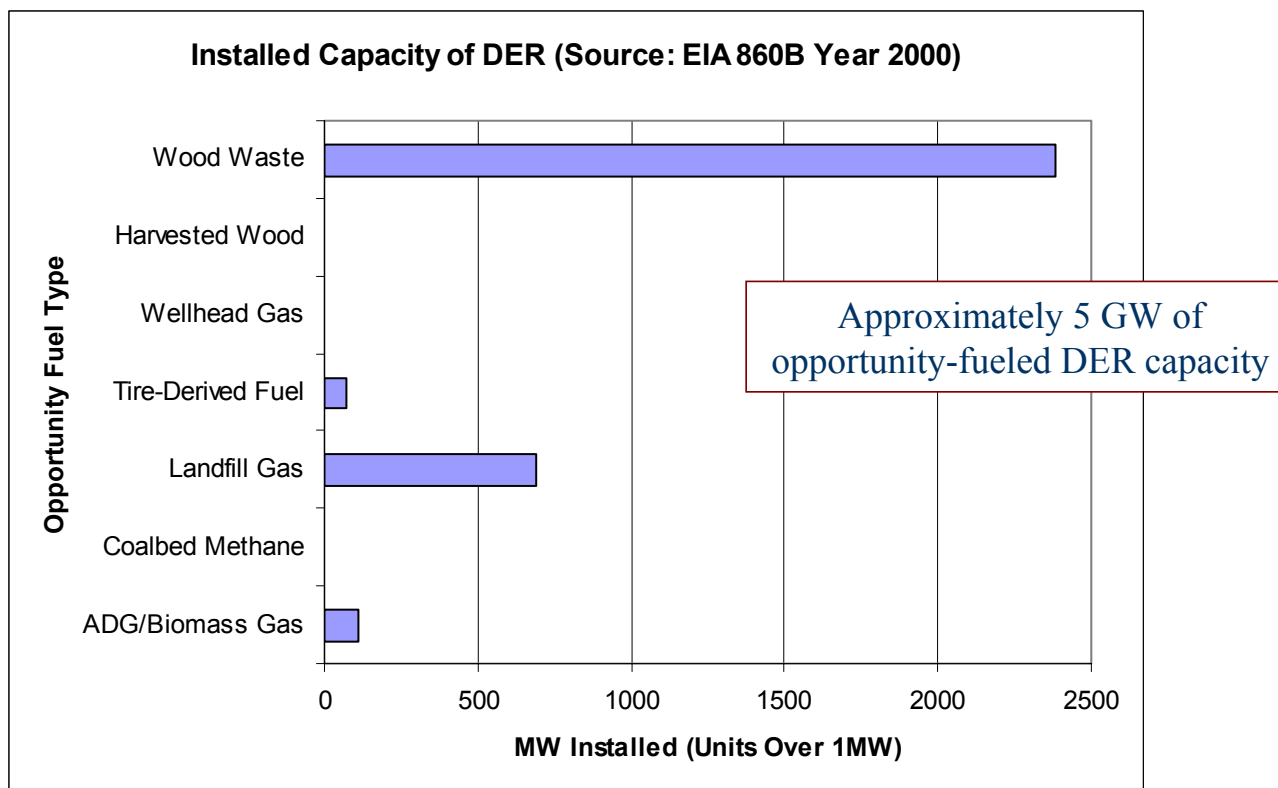
Fuel	Fuel Energy Content (Trillion Btu/yr)	Technical Potential Generating Capacity (Estimated, GW)
Anaerobic Digester Gas	600	9
Biomass Gas	6,450	90
Coalbed Methane	40	0.5
Landfill Gas	200	3
Tire-Derived Fuel	100	1.5
Wellhead Gas	10	0.1
Wood (Harvested)	680	10
Urban Wood Waste	550	8
Total	8,600	122

- Biomass gas offers most potential but requires most R&D to achieve
- Total fuel energy content without biomass gas is 2,200 Trillion BTU
- Total natural gas use for non-CHP power generation was 4,300 Trillion BTU in 2002
- Total natural gas use for CHP was 2,700 Trillion BTU in 2002

Notes: Fuel energy content based on all available resources that could be used as fuel.

Technical potential electric capacity was calculated assuming a 30 percent electric efficiency

Currently, Opportunity Fuels Contribute Little to U.S. Generating Capacity



Why are Opportunity Fuels Not Used More Often?

- Availability of fuel source often inconsistent in volume and in quality, resulting in variations in fuel volume, BTU content, and contaminants
- Often requires changes (adding \$) to generating equipment or purchasing processing equipment (digester, filtration, gasifier)
- Site where fuel is located has relatively low thermal and/or electric demand
- Costs to transport fuel to ideal site can kill projects
- Producing/processing fuel can be labor intensive

CHP Technology Considerations

- CHP technologies that can take advantage of opportunity fuels include:
 - Microturbines
 - Reciprocating engines
 - Combustion turbines
 - Steam turbine systems
 - Fuel cells
- With some fuels, (e.g. coalbed methane and processed TDF), existing technology requires little or no modifications or additional maintenance
- With other combinations of fuel/technology (ADG or LFG with combustion turbines), equipment and maintenance can cost 150-200% of the price of natural gas-fired units
- If required, auxiliary equipment (gasifiers for biomass gas, digesters for ADG, filtration equipment for low-Btu gases, etc.) will also add capital cost

Top Opportunity Fuel Candidates Are ...

- **Anaerobic Digester Gas** - over 6,800 municipal/industrial WWTPs could potentially benefit, as well as over 7,000 dairy farms and 11,000 hog farms - well over 6 GW of electric capacity could be achieved.
- **Biomass Gas** -any type of solid biomass fuel can be gasified - over 500 million tons (7,500 Trillion Btu) is available each year, potentially producing 90 GW.
- **Landfill Gas** - currently about 380 landfills participate in LFG-to-energy projects, of which about 280 produce electricity (2.3 GW) - over 1,000 more landfills could have project potential, which could add 4 GW.
- **Wood Waste** - can usually be obtained inexpensively, if not for free, and can be used easily in boiler-steam turbine systems - wood waste accounts for over 2 GW of US electric capacity, and there is potential for at least 8 GW more.
- Together, these fuels have the technical potential to add 108 GW of DER capacity

How Do We Progress Towards 92 GW of CHP?

- Do current natural prices make selling CHP tougher or is it still “just plain hard”?
- Can customers be persuaded that reliability and power security offer compelling benefits?
- Are alternative fuels a niche opportunity or do they have potential to provide substantial capacity?

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Cost of CHP Technologies to Use Opportunity Fuels

Fuel	Cost	Steam Turbine*	Gas Turbine	Combined Cycle	Recip. Engine	Microturbine	Fuel Cell
Anaerobic Digester Gas	Modify Existing Equip. (\$/kW)	\$70 - \$170	n/a	n/a	\$170 - \$390	\$0	n/a
	New Equipment (\$/kW)	\$650 - \$1,650	\$800 - \$2,100	\$725 - \$2,500	\$670 - \$1,540	\$970 - \$2,030	\$4,700 - \$6,000
	Maintenance (\$/kWh)	\$0.006 - \$0.013	\$0.006 - \$0.011	\$0.007 - \$0.016	\$0.013 - \$0.039	\$0.008 - \$0.017	\$0.012 - \$0.018
Biomass Gas**	Modify Existing Equip. (\$/kW)	\$600 - \$1,000	\$600 - \$1,000	\$600 - \$1,000	\$600 - \$1,000	\$600 - \$1,000	n/a
	New Equipment (\$/kW)	\$1,260 - \$2,650	\$1,150 - \$2,320	\$1,150 - \$2,760	\$1,260 - \$2,540	\$1,590 - \$3,090	\$5,330 - \$7,050
	Maintenance (\$/kWh)	\$0.006 - \$0.014	\$0.005 - \$0.011	\$0.006 - \$0.014	\$0.009 - \$0.026	\$0.007 - \$0.015	\$0.013 - \$0.021
Coalbed Methane	Modify Existing Equip. (\$/kW)	\$0	\$0	\$0	\$0	\$0	n/a
	New Equipment (\$/kW)	\$600 - \$1,500	\$500 - \$1,200	\$500 - \$1,600	\$600 - \$1,400	\$900 - \$1,900	\$4,300 - \$5,500
	Maintenance (\$/kWh)	\$0.005 - \$0.011	\$0.004 - \$0.008	\$0.005 - \$0.011	\$0.008 - \$0.023	\$0.006 - \$0.012	\$0.011 - \$0.017
Landfill Gas	Modify Existing Equip. (\$/kW)	\$70 - \$170	n/a	n/a	\$170 - \$390	\$0	n/a
	New Equipment (\$/kW)	\$650 - \$1,650	\$800 - \$2,100	\$725 - \$2,500	\$670 - \$1,540	\$970 - \$2,030	\$4,700 - \$6,000
	Maintenance (\$/kWh)	\$0.006 - \$0.013	\$0.006 - \$0.011	\$0.007 - \$0.016	\$0.013 - \$0.039	\$0.008 - \$0.017	\$0.012 - \$0.018
Tire-Derived Fuel	Modify Existing Equip. (\$/kW)	\$0	n/a	n/a	n/a	n/a	n/a
	New Equipment (\$/kW)	\$700 - \$1,800	n/a	n/a	n/a	n/a	n/a
	Maintenance (\$/kWh)	\$0.006 - \$0.014	n/a	n/a	n/a	n/a	n/a
Wellhead Gas	Modify Existing Equip. (\$/kW)	n/a	n/a	n/a	n/a	\$0	n/a
	New Equipment (\$/kW)	n/a	n/a	n/a	n/a	\$900 - \$1,900	n/a
	Maintenance (\$/kWh)	n/a	n/a	n/a	n/a	\$0.008 - \$0.017	n/a
Wood (Forest Residues)	Modify Existing Equip. (\$/kW)	\$140 - \$420	n/a	n/a	n/a	n/a	n/a
	New Equipment (\$/kW)	\$700 - \$1,800	n/a	n/a	n/a	n/a	n/a
	Maintenance (\$/kWh)	\$0.006 - \$0.014	n/a	n/a	n/a	n/a	n/a
Urban Wood Waste	Modify Existing Equip. (\$/kW)	\$150 - \$440	n/a	n/a	n/a	n/a	n/a
	New Equipment (\$/kW)	\$740 - \$1890	n/a	n/a	n/a	n/a	n/a
	Maintenance (\$/kWh)	\$0.007 - \$0.015	n/a	n/a	n/a	n/a	n/a

*including boiler
**including gasifier